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# Unfounded claims about productivity beyond density for reindeer pastoralism systems

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## Abstract

We point out problems with the article *Productivity beyond density: A critique of management models for reindeer pastoralism in Norway* by Marin and co-workers published in *Pastoralism* in 2020. In our opinion, there are several misleading claims about the governance of the reindeer pastoralist system in Norway, the Røros model for herd management and density dependence in reindeer herds in their article. We point out the errors in their empirical re-evaluation of previous work on the relationship between reindeer densities and the productivity and slaughter weights in herds. These errors have a significant bearing on their conclusions. We agree that weather variability has a substantial impact on reindeer body mass growth, fecundity and survival, but disagree with Marin et al. when they argue that reindeer densities are of minor importance for reindeer productivity and animal welfare.

**Keywords:** Semi-domesticated reindeer, Maximum sustainable yield, Seasonality, Animal welfare, Productivity, Regulations, Management

## Introduction

Already in the Reindeer Husbandry Act of 1933, it was specified that the Norwegian government could set an upper limit for the number of reindeer allowed onto pastures (Lov om reindriften 1933), and similar regulations are present in Swedish (Rennäringslag 1971) and Finnish (Finlex 1990) law. In Norway, maximum reindeer numbers were not initially enforced. This changed with the 1978 and 2007 revisions of the Reindeer Husbandry Act (Lov om reindrift 1978; 2007), and further, in the 2014 revision of the Act, the Norwegian government made it clear that it would enforce the law using severe fines if maximum reindeer numbers were exceeded (NRK 2014a). The motivation for introducing maximum reindeer numbers as a management tool was to ensure ecological sustainable resource management. More specifically, the criteria for setting maximum reindeer numbers were to hinder degradation of grazing resources, ensure high animal welfare standards in herds and ensure production of good quality slaughter animals (Ministry of Agriculture and Food 2009). Measures of calf production and slaughter weights were included in the method developed for determining maximum reindeer numbers (Johnsen and Benjaminsen 2017; Ministry of Agriculture and Food 2009). At the time of criteria development, 80% of responding reindeer herders agreed on the overall sustainability goal that reindeer numbers should be adjusted to pasture capacity to increase the condition of animals (Fig. 3 in Hausner et al. 2011). Also, after the enforcement of the maximum reindeer numbers in 2014, a survey by the national broadcasting company (NRK) of 27 reindeer district leaders in West Finnmark found that all except one leader agreed that a reduction in reindeer numbers was needed (NRK 2019). However, the processes of deciding on maximum reindeer numbers, the enforced reductions and the distribution of reductions between owners caused substantial

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conflicts between reindeer herders and the government (NRK 2014b, 2019).

In a recent article, Marin et al. (2020; from here onwards referred to as Marin et al.) contribute to the debate around the governance of the reindeer pastoralist system in Norway. They argue that enforcing maximum reindeer numbers is a poor management strategy and state that "The official governance of the reindeer pastoralist system in the north of Norway relies overwhelmingly on one central argument: that in order to maintain a sustainable system, maximum numbers and densities of reindeer, as well as certain herd structures, should be upheld. If these indicators are ignored, the argument goes, the consequences are resource degradation and economic collapse." Furthermore, Marin et al. "set out to investigate the validity of the premise that there is a strong relationship between density and carcass weights over the whole of Finnmark, based on official data", and "find that although the relationship is present, its explanatory power is not very strong in a variety of circumstances". Finally, they suggest productivity per area unit is a better measure than productivity per capita of reindeer and argue that this "reveals a different picture: rather than being a failed system marred by suffering animals and low economic returns, reindeer herding in western Finnmark becomes the most productive in Norway". Here, we discuss these claims. We find that Marin et al. give a biased description of the management regime and the current state of knowledge of density dependence in semi-domesticated reindeer herds. The main reason for this is their imprecise and erroneous use of references, data and methods.

## The official governance of the reindeer pastoralist system in the north of Norway

Marin et al.'s description of the history and current management policy of reindeer herding in Norway suffers from a lack of precision and is misleading because it does not distinguish between official management regulations, economic incentives, policy goals, advice and the authors' own unsubstantiated claims.

The main official regulation implemented by law is the maximum number of reindeer allowed in a reindeer management unit (Lov om reindrift 2007). In addition, there are economic incentives, as negotiated annually between the Norwegian government and the Saami Reindeer Herders' Association of Norway (NRL) (Ulvevadet and Hausner 2011; Ministry of Agriculture and Food 2020). Economic incentives for calf slaughtering were introduced in 1977 and have been the main instrument to promote calf slaughtering as a part of a social- and ecological-based sustainable management of reindeer herds, via increasing calf survival and growth up to the time of slaughter. In addition, a female-dominated herd structure is advised to increase meat production. We are unaware of any regulations in support of Marin et al.'s claim that economic subsidies directly depend on herd structure. Neither are we aware of any government representative stating that a deviation from the promoted herd structure will cause "resource degradation and economic collapse" as claimed by Marin et al. and note that Marin et al. provide no supporting references for their claims.

## The Røros model and its role in reindeer governance today

In the section "The Røros model", Marin et al. describe aspects of the herd management strategy developed around Røros in the 1970s and early 1980s. The Røros model is based on Lenvik and Aune (1988), Lenvik et al. (1988a, 1988b, 1988c) and Lenvik and Fjellheim (1988) and is summarized in Lenvik (2005). The main focus of the Røros model was to optimize the herd structure with respect to age, sex and adult female weight with the goal of achieving maximum calf production, survival and growth. However, the Røros model did not use "empirical evidence linking the carcass weight of reindeer to the stocking densities" and did not show "that reindeer herds with low densities and a high percentage of does had higher carcass weights" as claimed by Marin et al. These claims are stated without references, and we can only guess that Marin et al. have made the common mistake of interpreting all the publications written by the main researcher behind the Røros model, Dag Lenvik, as being descriptions of the Røros model. Marin et al. also claim that the "establishment of thresholds for the highest number of reindeer allowed in a given area" was a consequence of research on how to maximize meat production—the Røros model. Again, Marin et al. have no references to support this claim. It seems noteworthy that both the official report by Ims and Kosmo (2001) suggesting a method for setting maximum reindeer numbers for West Finnmark and the later document describing "criteria/indicators for ecologically sustainable reindeer numbers" (Ministry of Agriculture and Food 2009) include no results from or references to the Røros model. The role of "the Røros model" in today's governmental management of reindeer is in our opinion given too much emphasis in Marin et al.

In "Critiquing the model – Quantitative assessments", Marin et al. focus on the concept of maximum sustainable yield (MSY) and suggest it to be indicated by Lenvik (1990, Figure 4, reproduced as Fig. 2 in Marin et al.). However, MSY was neither a concept used in the "Røros model" or in the paper by Lenvik (1990) that they refer to, neither was the relationship (Lenvik 1990, Figure 4) used to support the Røros model in herd management, as implicated by Marin et al. Lenvik's (1990) Figure 4 shows estimates of meat production against reindeer numbers in West Finnmark and was used as support for the argument that a reduction of reindeer numbers from 105,000 to 67,000 would not reduce meat production in the area substantially.

Inspired by Lenvik (1990, Fig. 2 in Marin et al.), Marin et al. suggest a different measure of productivity for reindeer in West Finnmark, using the relationship between change in herd size from the end of March in one year to the same time the following year and the number of animals slaughtered within this period (predominantly in the autumn and early winter). They fitted a non-linear function to these estimates and reindeer numbers and interpreted their results as measuring MSY. This method has no methodological support in previously published work. It is well known that in seasonal environments, the seasonal timing of harvesting in relation to seasonal patterns of mortality has implications for the optimal harvest strategy (Kokko and Lindström 1998; Boyce et al. 1999; Jonzen and Lundberg 1999; Xu et al. 2005), results that are ignored in the attempt by Marin et al. to estimate MSY. If significant mortality occurs between the time of harvest and the census date at the end of March, as is expected for reindeer during winter, their method is unsuitable for estimating MSY. We note that the estimates of meat production used by Lenvik (1990) are also affected by such methodological problems.

## Carcass weights and density

Marin et al. assess a report from the Norwegian Reindeer Management Agency (Ims and Kosmo 2001) that described reindeer districts in western Finnmark and suggested a method for estimating the maximum reindeer numbers. In particular, they focus on an analysis of slaughter data from the autumns in 1998–2000 which shows a strong relationship ($R^2$ = 0.70) between the average carcass weight of slaughtered 1-year-old males (*varit*) and reindeer densities. Marin et al. claim they redo the analysis with more of the same data, i.e. data from more years (1980–2012), and find a much weaker relationship between *varit* slaughter weights and reindeer densities ($R^2$ = 0.24) than Ims and Kosmo (2001). They interpret this as evidence that the relationship is weak over a longer time period. However, inspection of the supplementary data they provide with their paper reveals that Marin et al. has not used "more of the same data". The main discrepancies between what Marin et al. state they do and what they actually do are that (1) Marin et al. use only data from the "Kautokeino" districts (and not the whole of Finnmark as they state in the abstract), while Ims and Kosmo (2001) used districts associated with both Kautokeino and Karasjok; (2) Marin et al. do not perform the quality control of data performed by Ims and Kosmo (2001). Before analysis, Ims and Kosmo (2001) reported that they performed extensive quality control of the data to reduce sample variance and bias. In particular, they discarded annual estimates based on small sample sizes (< 25) and carcass weight data from *varit* slaughtered after the autumn rut—because the rut is accompanied by weight loss, data that seems to have been included in Marin et al.; (3) Contrary to Ims and Kosmo (2001), Marin et al. use reindeer densities from the end of the reindeer herding year rather than the onset of the reindeer herding year as their predictor variable; and (4) Marin et al. include data for *varit* from only 1997–2012 and not 1980–2012 as claimed in their text. Furthermore, a reanalysis of the supplementary data file accompanying Marin et al. shows that the relatively weak relationship between *varit* weights and reindeer densities is also present in the 1998–2001 subset of the data they use ($R^2$ = 0.29), thereby differing from the results reported by Ims and Kosmo (2001). Our conclusion is that the discrepancy between the findings in Marin et al and Ims and Kosmo (2001) is due to a difference in the data used in the analysis rather than more years of the same data.

To evaluate this topic further, we revisited the analysis of Ims and Kosmo (2001) using data on average *varit* slaughter weights and reindeer numbers from mainland districts associated with Kautokeino and Karasjok in Finnmark county for 2000–2019 obtained from www.reinbase.no. We supplemented these data with information from 1997/1998 and 1998/1999 from Reindriftsforvaltningen (1999, 2000). In our analysis, we excluded observations (1) with less than 25 *varit* reported slaughtered; (2) from district 36, since there is no record of them slaughtering *varit* before the rut (www.reinbase.no); and (3) from "island" districts, to follow the strategy adopted in Ims and Kosmo (2001) as close as possible. We also excluded district 16A-D as Ims and Kosmo used siida-level information from these districts, and this information was not available for us for 1998 and 1999. Reindeer densities were calculated using the total area of the summer pastures with no adjustments (Landbruksdirektoratet 2019a). Following Ims and Kosmo (2001) and Marin et al., we fitted the natural logarithm of reindeer densities as a linear predictor of district-level average *varit* slaughter weights. When using data from the same years as used by Ims and Kosmo (2001), reindeer densities explained 65% of the variance in *varit* weights ($R^2$ = 0.65) in these data (Fig. 1). This is a substantially higher value than the one obtained using the data in Marin et al. ($R^2$ = 0.29) and close to the value obtained by Ims and Kosmo (2001, $R^2$ = 0.70). The main difference between the data used by us and Ims and Kosmo (2001) is their stricter quality control of data, and Ims and Kosmo (2001) using net area of summer pastures (total area minus area with no vegetation cover) when

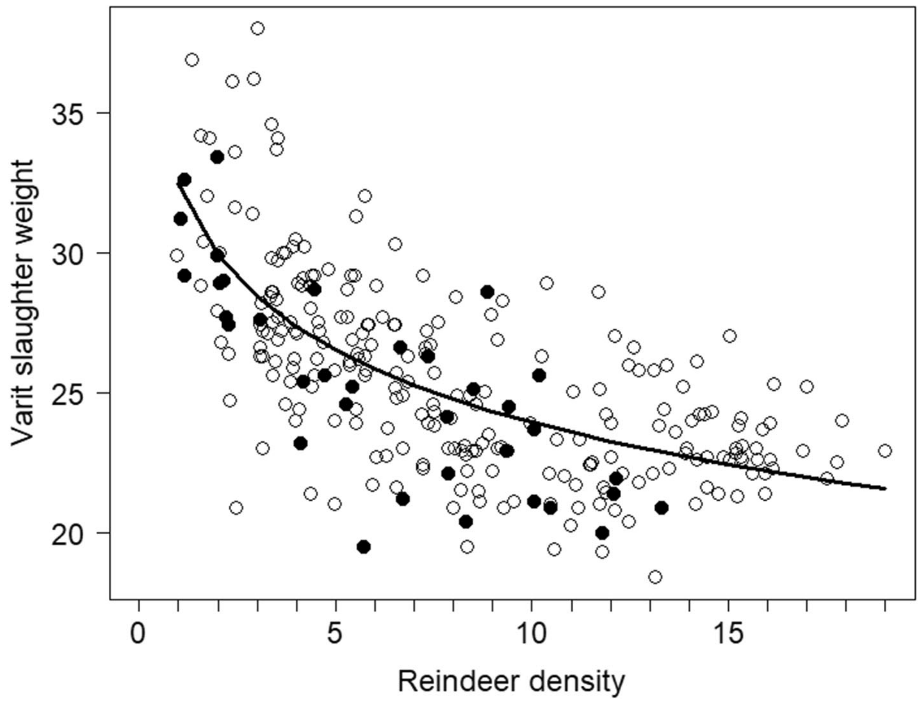


**Fig. 1** Estimates of average *varit* slaughter weights (kg) plotted against district-level summer population densities ($km^{-2}$). Filled circles are estimates from the years used by Ims and Kosmo (2001, slaughter data from autumns of 1998–2000), and open circles are for the subsequent years up to 2019 and 1997/1998. The line gives the best fit linear regression line with log(density) fitted as a predictor variable (estimated regression coefficients: intercept = 32.41, SE = 0.47, ln(density) slope = − 3.71, SE = 0.24)

calculating densities. When extending our time series to cover the 1998–2019 period, the variance explained by density decreased in our dataset, but still, density explained almost half of the variation in *varit* slaughter weights ($R^2$ = 0.47, Fig. 1, data and analysis script in supplementary information).

Our interpretation is therefore contrary to the claim by Marin et al.; the relationship between slaughter weights and densities is not substantially weakened by extending the time series. Also, models that better describe the structure of these data support that density is an important predictor of *varit* weights. We extended the simple linear regression model above by fitting year and district as random intercept effects and log(density) as a random slope effect that varied between districts. The model confirmed a negative fixed effect estimate of log(density) (estimate = − 3.12, SE = 0.41). The fixed effect of log(density) explains close to half of the variance ($R^2$ = 0.37) explained by the total model including random effects ($R^2$ = 0.80, estimated following Johnson 2014). However, contrary to what is found by Holand et al. (2010) in *varit* slaughter weight data from partly overlapping time periods (1983–1987 and 1996–2004), we found little evidence for the between-district variance in log(density) slopes to differ from zero (estimated variance = 0.39, likelihood ratio test for the difference from zero: $P < 0.16$).

## Productivity per area unit

Marin et al. suggest “that productivity per area unit can be at least as relevant as carcass weights” and that “a measure of productivity in kilogrammes per square kilometre reveals a different picture: rather than being a failed system marred by suffering animals and low economic returns, reindeer herding in western Finnmark becomes the most productive in Norway”.

We agree that meat production per square kilometre is a useful measure of productivity. Carcass mass seems more relevant as an indicator of animal condition in the herds (Tveraa et al. 2007; Lundqvist et al. 2009; Olofsson et al. 2011). It is also generally accepted that areas differ in their environmental suitability for reindeer herding (e.g. Ims and Kosmo 2001; Helle and Kojola 2006; Lundqvist et al. 2009), and clearly, Finnmark is well-suited for reindeer herding and produces most of the reindeer meat in Norway (Landbruksdirektoratet 2019a). However, West Finnmark experiences high losses of reindeer and low economic returns. As such, we disagree that high productivity in kilogrammes per square kilometre is a suitable measure to evaluate “suffering animals” and “economic returns” as implied by Marin et al.’s statement.

By way of explanation, we follow Marin et al. and compare the Røros and Kautokeino region. In recent years, the proportion of marked calves lost on pasture has been roughly twice as high (30–60% vs 10–30%, for 2005–2019, www.reinbase.no), and net income per enterprise was only one third (183 vs 600 KNOK in 2018, Landbruksdirektoratet 2019b) in the Kautokeino region when compared with the Røros region. This suggests there are substantial differences between the two systems with respect to animal welfare and economic returns. Variation in large predator densities does not explain this difference (Tveraa et al. 2014; Bischof et al. 2020). We also note that maximizing reindeer meat production per area unit may compromise other ecosystem services, such as biodiversity, and thereby more holistic goals for sustainable ecosystem-based management.

## Current state of knowledge

Marin et al. give the impression that much of the ecological literature on reindeer population dynamics focuses solely on density effects. However, the vast majority of articles published since the turn of the century have a focus on weather and/or climate and/or vegetation growth as key factors of importance in addition to density (e.g. for semi-domesticated reindeer: Helle and Kojola 1994, 2008, Weladji and Holand 2003, Tveraa et al. 2007, 2013, 2014, Lundqvist et al. 2009, Holand et al. 2010, Hobbs et al. 2012, Hendrichsen and Tyler 2014, Henden et al. 2021; for wild reindeer/caribou: Aanes et al. 2000, Tyler 2010, Fauchald et al. 2017, Albon et al. 2017, Hansen et al. 2019). Nevertheless, current knowledge is that population density is an important predictor of the population dynamics of reindeer, as it is for many other species that interact with components of many-faceted, temporally fluctuating and spatially varying natural ecosystems. In such contexts, as suggested by, e.g., Tyler (2010) and Tveraa et al. (2007), density dependence typically interacts with density-independent factors (e.g. weather/climatic variation). This implies that density dependence cannot be understood independently from the state of the other drivers, and leads to populations with high densities and/or low body mass being more prone to high mortality in difficult winters (Tveraa et al. 2007, 2013, 2014; Tyler 2010; Hansen et al. 2019). Moreover, density dependence can be delayed and/or non-linear because it may result from combinations of ecological interactions (plant-herbivore, host-parasite, predator-prey) that are mediated through different life history parameters.

Already in the seminal paper by Sæther (1997) on mechanisms generating population fluctuations in ungulates (and cited by Marin et al.), it was emphasized that their population dynamics are strongly influenced by a combination of stochastic variation in the environment and population density, and furthermore, that body mass is a key variable in explaining these processes. Later, understanding the form and strength of density dependence under various environmental conditions, and how variation in animal body mass is both a response to and an explanatory factor of population dynamics, has received much attention. Based on this accumulated knowledge, stochastic harvest models have been developed (Lande et al. 2003), and stochastic simulations (e.g. Bårdsen et al. 2014) have been used in exploring optimal strategies for reindeer harvesting.

## Conclusion

Herbivore populations subjected to natural food web interactions in stochastically fluctuating abiotic environments are expected to exhibit complex dynamics. For semi-domestic reindeer, additional complexities are due to socio-economic factors. Consequently, finding rational management strategies is challenging, and the regulations and incentives employed by the Norwegian government have in some respects been malfunctioning (Hausner et al. 2011).

We agree with Marin et al. and others (e.g. Bernes et al. 2015) that it is prudent to use food web state variables as predictors of the productivity of reindeer herds (e.g. Henden et al. 2021)—in particular, in the era of rapid climate change (Ims and Yoccoz 2017). However, we are confident that reindeer body weight and population density will continue to be valuable indicators for scientists, herders and management authorities.

### Abbreviations

MSY: Maximum sustainable yield; Marin et al.: Marin, A., E. Sjaastad, T. A. Benjaminsen, M. N. M. Sara, and E. J. L. Borgenvik. 2020. Productivity beyond density: A critique of management models for reindeer pastoralism in Norway. Pastoralism 10:9. doi:10.1186/s13570-020-00164-3

## Supplementary Information

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**Additional file 1.** Data from the supplementary material of Marin et al. (2020).

**Additional file 2.** Data on average varit slaughter weights from the years 1998-2019.

**Additional file 3.** R–script used for statistical analyses in this study.

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### Authors' contributions

AS and TT analysed the data and wrote the first version of the manuscript. All authors contributed significantly to improve the manuscript and read and approved the final manuscript.

### Authors' information

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#### Availability of data and materials
The data and R–script used for statistical analyses in this study are included in Supplementary information files

## Declarations

#### Ethics approval and consent to participate
Not applicable.

#### Consent for publication
Not applicable.

#### Competing interests
The authors declare that they have no competing interests.

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